COMPARISON OF RELATIVE AND ABSOLUTE PRECISION OF OHIO'S WIDE AREA GPS NETWORK INCLUDING THE COMPARISON WITH ALTERNATIVE METHODS

A Thesis

Presented in Partial Fulfillment of the Requirements for

the Degree Bachelors of Science with Honors in the

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By

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ABSTRACT

Wide Area RTK (Real Time Kinematic) networks have proven successful in the modeling of errors that limit traditional RTK techniques. Although the technologies of existing Wide Area RTK networks are similar, each network exhibits unique characteristics based on local environmental variables. These local environmental variables consist of factors unique to the network design, such as reference station placement, distance between reference stations, local gravity anomalies and multipath at the reference stations.

Ohio maintains 52 Continually Operating Reference Stations (CORS) that make up the basis for a Wide Area RTK network. This study is intended to show that the current Wide Area RTK network in Ohio is comparable in precision and accuracy to a post processed kinematic solution. To accomplish this task a rover was placed 140 meters away from a CORS station that lies within the Ohio network. The data was then collected and processed, revealing that the Wide Area RTK solution matched the alternative solution. This baseline distance was chosen carefully to form a base study for future experiments. The strength of the Wide Area RTK solution is to allow increased baseline length between the rover and the base station while maintaining centimeter level precision.

The current site was chosen to examine how the effects of local rover environmental variables such as multipath affect the two solution types. The results of this test prove that both solution algorithms are affected by multipath in a similar manor. This test also points out key advantages and disadvantages of a Wide Area RTK solution. These results will allow future tests to be conducted on the Ohio network with increased confidence.

Dedicated in the loving memory of John R. Lowe

ACKNOWLEDGMENTS

I wish to thank my honors adviser, Dr. Dorota Brzezinska, for nurturing and developing my knowledge and interest of the Global Position System.

I wish to thank John Ray and the Ohio Department of Transportation Office of Aerial Engineering, for providing time, hardware, and technical supervision.

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I would like to send special thanks out to my family; the last four years have been quite a ride, thanks for all of your prayers and patience.

I would like to send special thanks out to my wife, thank you for understanding why all of the time apart was necessary, thank you for everything.

VITA

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PUBLICATIONS

Not Applicable

FIELDS OF STUDY

Major Field: Geomatics Engineering

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CHAPTER ONE

INTRODUCTION

The use of the Global Positioning System (GPS) to determine centimeter level positions over longer distances is a highly researched topic. The fruits of this research have been seen by the private and public disciplines that require an increase in accuracy and a decrease in post-processing time. One system that has been developed to provide centimeter level positions, over long distances (30-100km) in real-time, is known as the Wide Area Real Time Kinematic (RTK) network (Landau, Vollath, and Chen). This system relies on Continually Operating Reference Stations (CORS) to collect GPS data in a network environment. The CORS stations collect data continuously allowing the data to be streamed to a network computer in real-time.

The data collected from the CORS stations in the network is then processed at the central computer. Having the same of epoch of data for multiple CORS stations, allows for advanced forms of error modeling (Bagge, Wübbena and Schmitz). The ability to model errors is the main way in which the Wide Area RTK system can achieve increased accuracy with inter-base station distances approaching 100km. The limitation of single baseline differential GPS techniques is the ability to model errors accurately, between the base station and rover as baseline length increases.

A couple of the main variables that attribute to this factor are differing satellite geometry and local ionospheric differences. There are several techniques that a Wide Area RTK network can use to deal with the deficiencies of differential GPS, the most common are the FKP, VRS and the modified Least Squares approach (Bagge, Wübbena and Schmitz). This paper will investigate the technique used by the Ohio Department of Transportation, the creation of a Virtual Reference Station (VRS). The VRS technique uses a network of CORS receivers to monitor and model errors at the base stations, which then can be used to interpolate corrections to a rover.

The best explanation on how the VRS actually corrects the rover for errors is found in the Trimble GPSnet documentation. The rover will send a navigation solution (Single Point Position) in the form of a GGA record in the National Marine Electronics Association (NMEA) standard. GPSNET then finds the closest CORS station to the SPP solution. "It uses the SPP solution as position of a Virtual Reference Station it generates. When a suitable station is found, the RTCM Generator goes into VRS-Mode, which means it applies the network-corrections to the selected station's raw data and transforms it to the VRS position. If no network-corrections are available, the RTCM Generator enters into the fallback mode RAW-Mode (if configured) - it then works like a RTCM single Station." (Landau, Vollath, Chen). Figure 1 in appendix A shows a flow chart for the VRS network.

The idea of having a network of reference stations (CORS) interpolate error corrections such as Ionospheric, Tropospheric and geometric to a virtual base station any where inside the network allows for extremely short VRS base station to rover distances.

The Wide Area RTK network developed by the state of Ohio uses the VRS technique to create corrections in real-time. Ohio's system uses 52 CORS stations as a basis for the network. The data from the 52 reference stations streams via LAN lines to a centralized set of servers. The central servers facilitate the connection of users with the VRS processor. The Ohio system utilizes cellular technology to connect the rover with the VRS processor. The real time capabilities of the current Ohio system are dependent on the cellular network infrastructure. The VRS system is dependent on cellular technology because of the need for two-way communication. One advantage of having a cellular link is the ability to send and receive data. The main disadvantage to cellular technology is the limited amount of coverage in rural areas. In Ohio, the cellular infrastructure covers most major cities and the majority of interstate routes. The cellular network is expected to increase in density as demand increases in non-coverage areas.

This test was designed to establish confidence in the V.R.S. network by examining the affects of local environmental variables (i.e. multipath) on the current network. By starting with a very short baseline (140m), error sources such as Ionospheric, Tropospheric and differing geometry will be minimized. This will allow the data to show differences caused by changing satellite geometry and multipath more clearly.

CHAPTER TWO

THE EXPERIMENT

The procedures used for this experiment were intended to reduce as many errors as possible through careful setup and planning. The experiment required close control of hardware, location and time of testing. For this experiment, appropriate hardware was chosen to allow for simultaneous collection of static data and V.R.S point positions. As seen in Figure 2, Appendix A, one Trimble Zephyr geodetic antenna with a ground plane was mounted to a two meter fixed height tripod. Sand bags were used to secure the tripod over a stable control point. The use of one antenna with two receivers allows for further minimization of errors caused by multiple equipment configuration such as centering error, and phase center shift.

The location for this experiment was chosen to meet the following criteria. The location must have a high order control point, the location must be secure, and there must be a constant power source to run the equipment for an extended period. The site was also chosen to simulate real world GPS survey conditions, with several trees, and power poles within the field of view. The coordinates of the control point were originally established during the High Accuracy Reference Network (HARN) survey performed by the National Geodetic Survey (NGS).

Having a known control point was necessary to check how closely the absolute positions of the two different solutions matched a high accuracy position (A order horizontal). Security was a high priority because the equipment would be left unattended for several hours and buying replacement equipment was not an option.

After finding a suitable location, the next step was to define the data collection process. Figure three in appendix A shows a detailed view of the data collection phase of this experiment. Two Trimble dual frequency, survey grade receivers were chosen to collect the data. One of the receivers stored the data as a static session, to be post processed as a continuous kinematic observation. The second receiver was connected to a Trimble TSCE data collector, which stored point positions internally. The data collector used Trimble Survey Controller version 10.72, which allowed the collection of a real time VRS solution via a GSM cell phone.

FIGURE 2.1

The data collection software was setup to auto increment a corrected point solution, every 15 seconds. This process continued for 24 hours, allowing for two full satellite cycles. The process for collecting a V.R.S. point solution while using Trimble Survey Controller can differ as settings inside the software change. The process used to collect corrected data is outlined in the following steps. The process starts by having the GPSnet software collect data from a minimum of three reference stations. The software will then process the raw data, and correct for satellite ephemeris, cycle slips and phase center errors. The next step is for a rover to send a navigation solution (SPP solution) in the form of a GGA record in the National Marine Electronics Association (NMEA) standard to the server via a GSM cellular phone. Then the RTCM VRS Generator module, located within GPSnet, will calculate the corrections necessary to place a virtual reference station at the NMEA position. This is done by using the network corrections found by the GPSnet module to correct the raw data at the closest reference station. Then the virtual reference station is interpolated from the closest reference station.

Once the virtual reference station is simulated, the software on the rover can solve for integer ambiguity by using double differencing. From this point on, the process is very similar to traditional RTK. The rover's position is considered to be in float mode until the integer ambiguity can be solved. Once the baseline is resolved, the position is then considered to be fixed.

For this experiment, one epoch of fixed position was collected every 15 seconds. This would vary from control point GPS field collection in that, a point would normally be a collection of fixed epoch's adjusted to create one point.

Unlike the V.R.S. solution, the static session required post processing to obtain a meaningful solution. The static data processing was completed using Trimble Geomatics Office. The processing style used for this experiment was continuous kinematic. To accomplish this task, the file type was changed from a static file to a continuous kinematic file. The next step was to download a static data file for the reference station. This data was obtained from the National Geodetic Survey web site. The CORS station used for this experiment is named COLB and is a part of the Ohio CORS network developed and maintained by the Ohio Department of Transportation.

The next step was to adjust the coordinates of COLB to the published values by entering the antenna reference point. Once this was done, the kinematic session was processed and the solutions were created. A sample baseline processing report is provided in appendix B. This report shows important information about the style of processing, important settings, and residual plots for each satellite.

CHAPTER THREE

THE RESULTS

The final step in this experiment was to analyze the differences between the V.R.S. point solutions and the alternative solutions. Trimble Geomatics Office software was used to process both sets of data. This software was also used to create solution reports and plots. Microsoft Excel was used for statistical testing and histogram plots. Each data set was broken down into hourly blocks with 240 points. The total number of points for the twenty-four hour session was well over 5,900. With this large of a data set, special care was taken to normalize the data before statistical testing. This was done to prevent rounding errors while calculating the standard deviation. The results for the relative position for both data sets showed that the two techniques could produce similar results. Figure 3.1 shows the mean position for the entire data set.

	Static total			**VRS total**	
	Mean	**1-Sigma**		**mean**	**1-Sigma**
Easting (m)	553492.482	0.005	**Easting (m)**	553492.484	0.007
Northing(m)	217780.526	0.007	**Northing(m)**	217780.528	0.009
Elevation(m)	217.802	0.015	**Elevation(m)**	217.806	0.018

FIGURE 3.1

The results show a difference in Easting and Northing of two millimeters and a difference in elevation of 4 millimeters. The overall difference between the two solution types shows remarkable similarity. Figure four in appendix A is a graphical representation of the two complete data sets combined. The next relative comparison was done with data that was separated into one-hour blocks. Figure five in appendix A shows the differences for each hour. Overall, the relative accuracy of the V.R.S. solution is very close to the alternative solution. The difference between the horizontal positions of the two solutions is well within 10 millimeters.

The next step in this experiment was to determine the absolute accuracy of the two techniques. This was accomplished by looking at the difference between a published position and the two solutions. The published position was obtained from the National Geodetic Survey and is considered a first order (A) horizontal control point. The point name is AE104 and the monument is a solid steel rod driven to refusal and encased within a greased sleeve. Figure 3.2 shows the difference between the published point and the two solutions.

	Difference AE104 - static	difference AE104 – V.R.S.
Easting	-0.008	-0.010
Northing	0.001	0.001
Elevation	-0.002	-0.006

FIGURE 3.2

The results of this portion of the test provide evidence that both techniques provide centimeter level accuracy. The standard deviations for both techniques are within two centimeters horizontal and three centimeters vertical.

After separating the data into one hour blocks, an interesting phenomenon was noticed during the twelfth hour (2:00 am ESTD) of the experiment. The standard deviation of the Northing of both solutions showed an increase (Figure 6, Appendix A & Figure 3.3).

	static hour 12			VRS hour 12	
	Mean	1-Sigma		mean	1-Sigma
Easting (m)	553492.482	0.004	Easting (m)	553492.484	0.005
Northing(m)	217780.512	0.019	Northing(m)	217780.515	0.023
Elevation(m)	217.805	0.025	Elevation(m)	217.828	0.031

FIGURE 3.3

This phenomenon was not common to other times during the experiment. The first step taken to investigate this phenomenon was to look at the Position Dilution Of Precision (PDOP). This factor is normally a good indicator of the solution quality. A solution with a high PDOP (above 6) could indicate problems with the data set. After a short investigation, the PDOP factor for both processing styles was ruled out. The calculated PDOP was never more than two.

The next step was to look into atmospheric disturbance for the time period in question. High ionospheric activity can cause signal interference, cycle slips, data loss and is often overlooked as the cause of such problems. The ionospheric activity for the period in question was considered low (indexed below one) by data collected from the SOHO satellite.

The next step was to look at the processing reports produced by the post processing session. After several qualified opinions, nothing really jumped out as being abnormal. The last step was to compare an obstruction diagram of the site with a plot of satellites used during processing. Several trees were found to be within the field of view. The trees were above the thirteen-degree mask elevation cutoff, set for the GPS antenna. The data from the satellites that passed thru the trees was then removed, and the data was re-processed. After the reprocessing, the standard deviation fell to a normal level. The removal of satellite data that has interference from obstructions will greatly reduce the effects of multipath and signal interference. After re-processing the data to remove satellite obstructions, the solution for the twelfth hour became closer to the expectation drawn from the rest of the experiment. Figure 3.4 shows the before and after statistics for the twelfth hour.

	static hour 12			Static hour 12 multipath reduced	
	Mean	**1-Sigma**		**mean**	**1-Sigma**
Easting (m)	553492.482	0.004	**Easting (m)**	553492.477	0.004
Northing(m)	217780.512	0.019	**Northing(m)**	217780.529	0.010
Elevation(m)	217.805	0.025	**Elevation(m)**	217.804804	0.015

FIGURE 3.4

The important lessons learned while conducting this experiment will provide a good base of understanding to continue testing Ohio's V.R.S. network. This experiment provides proof that the V.R.S. network solution is comparable to a post-processed solution over short distances. One disadvantage of the V.R.S. network is the inability to remove satellite data efficiently during field operation. Another important lesson learned is that high number of satellites are not always the best scenario. During the re-processing, three satellites out of a total of eight caused a bias in the data set. In this case, five satellites with good data provided a better solution than eight satellites.

One advantage of post-processing is the ability to filter out conspicuous satellites during processing. This advantage is only applicable when time to post-process the data is available. The main advantage to the V.R.S network is that it provides real-time positioning with centimeter level accuracy. The main way for a real-time user to combat the bias found in this experiment, is to use good data collection techniques. By limiting the amount of multipath during data collection, results that are more confident can be obtained. For the situation where overhead obstructions cannot be avoided, redundant data and proper field notes should be taken, so that proper weight can be applied to the solution. Future experiments will look to test the Wide Area RTK network in Ohio for the ability to provide centimeter level at extended baseline lengths. From this experiment, a good understanding how multipath and obstructions found at the rover will affect the V.R.S. solution.

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Introduction into Real-Time Network Adjustment with Geo++ GNSMART
Andreas Bagge, Gerhard Wübbena, Martin Schmitz. GeoInformation Workshop 2004, Istanbul Kultur University, September 20-26, Antalya

GPSNET VRS™ Software User Guide, Trimble Version 2.10 Revision A, July 2003

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APPENDIX A

EXPERIMENT DATA

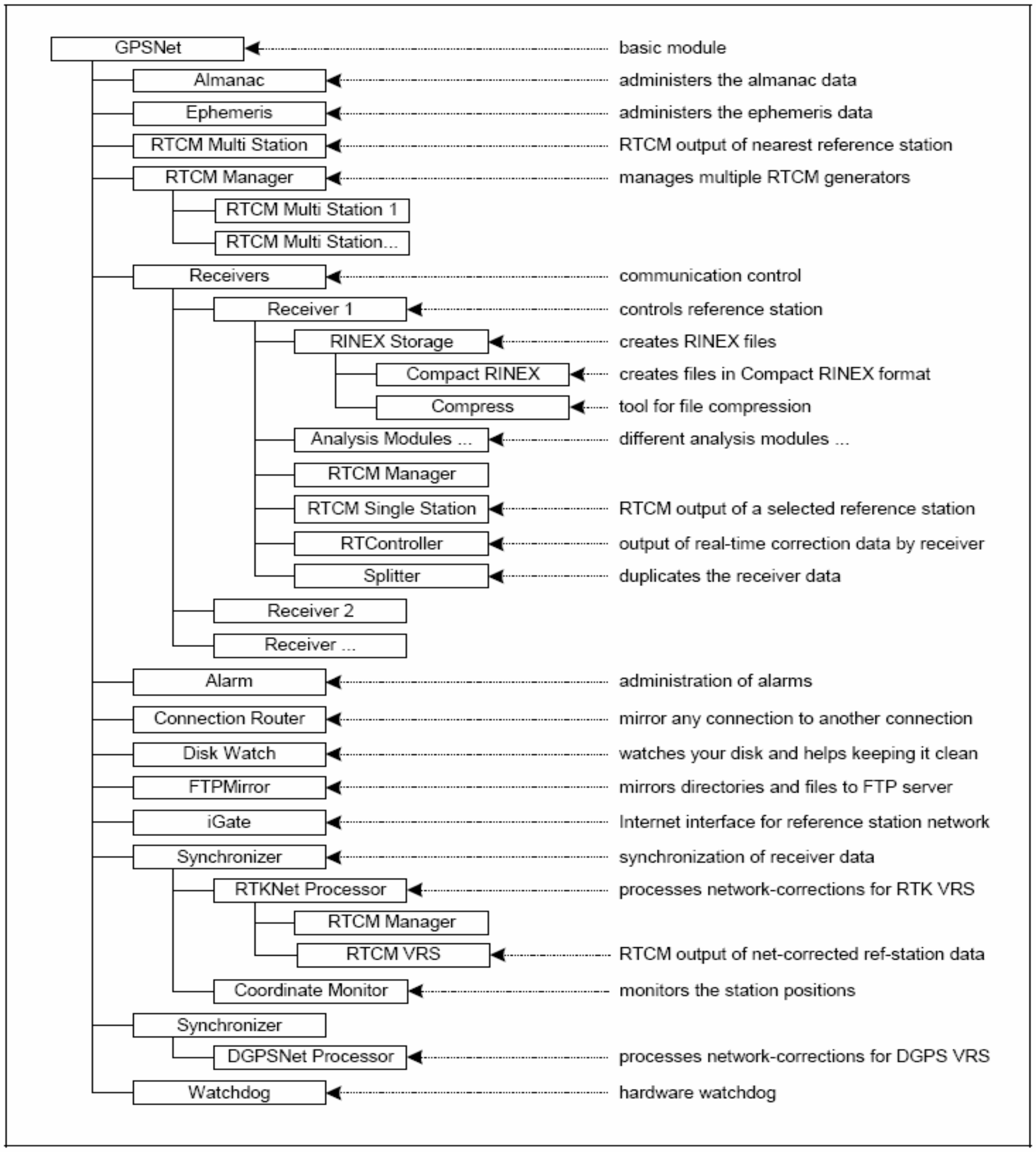

GPSNet
basic module
Almanac
administers the almanac data
Ephemeris
administers the ephemeris data
RTCM Multi Station
RTCM output of nearest reference station
RTCM Manager
manages multiple RTCM generators
RTCM Multi Station 1
RTCM Multi Station...
Receivers
communication control
Receiver 1
controls reference station
RINEX Storage
creates RINEX files
Compact RINEX
creates files in Compact RINEX format
Compress
tool for file compression
Analysis Modules ...
different analysis modules ...
RTCM Manager
RTCM Single Station
RTCM output of a selected reference station
RTController
output of real-time correction data by receiver
Splitter
duplicates the receiver data
Receiver 2
Receiver ...
Alarm
administration of alarms
Connection Router
mirror any connection to another connection
Disk Watch
watches your disk and helps keeping it clean
FTPMirror
mirrors directories and files to FTP server
iGate
Internet interface for reference station network
Synchronizer
synchronization of receiver data
RTKNet Processor
processes network-corrections for RTK VRS
RTCM Manager
RTCM VRS
RTCM output of net-corrected ref-station data
Coordinate Monitor
monitors the station positions
Synchronizer
DGPSNet Processor
processes network-corrections for DGPS VRS
Watchdog
hardware watchdog

FIGURE 1

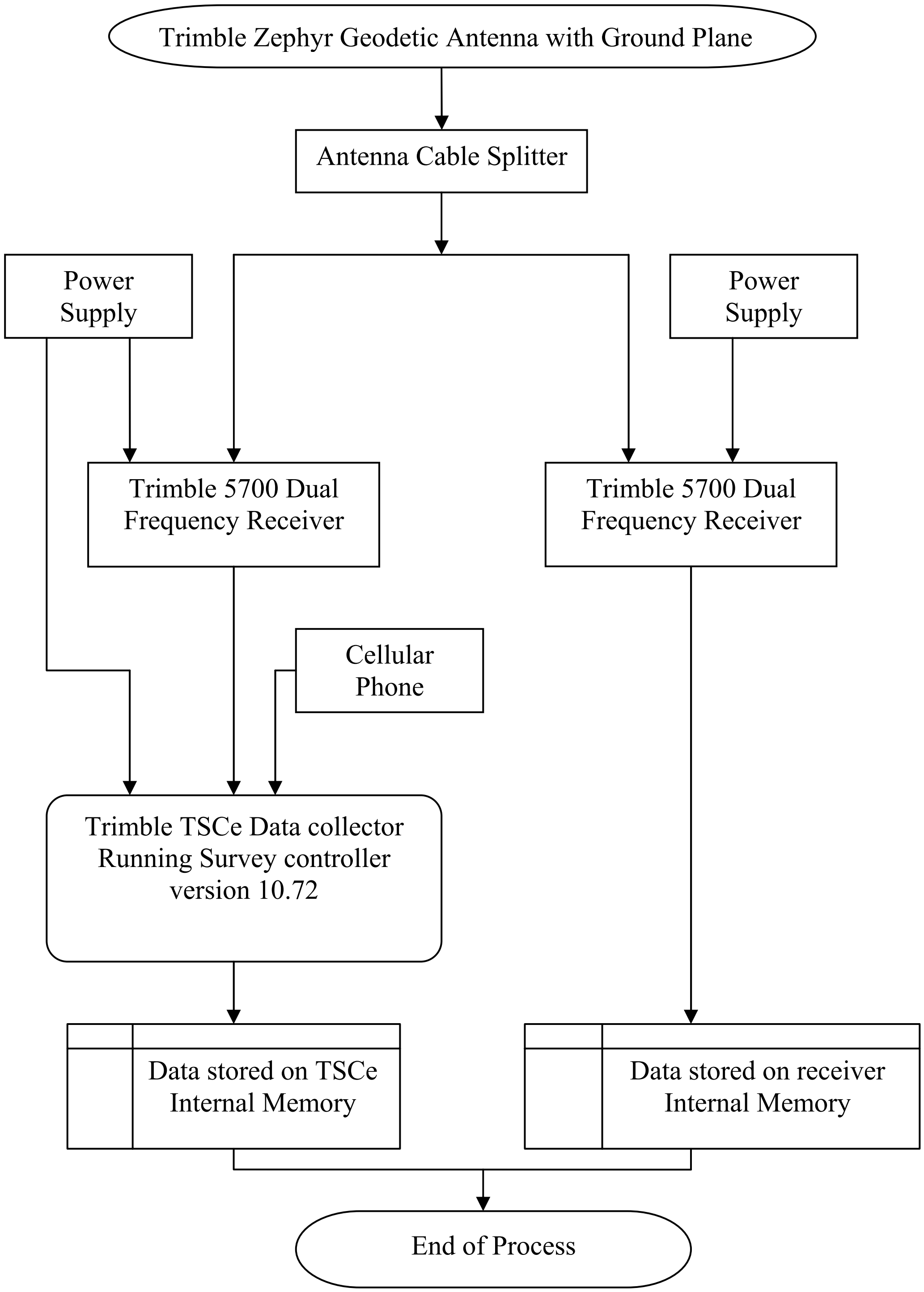

Trimble Zephyr Geodetic Antenna with Ground Plane
Antenna Cable Splitter
Power Supply
Power Supply
Trimble 5700 Dual Frequency Receiver
Trimble 5700 Dual Frequency Receiver
Cellular Phone
Trimble TSCe Data collector Running Survey controller version 10.72
Data stored on TSCe Internal Memory
Data stored on receiver Internal Memory
End of Process

FIGURE 2

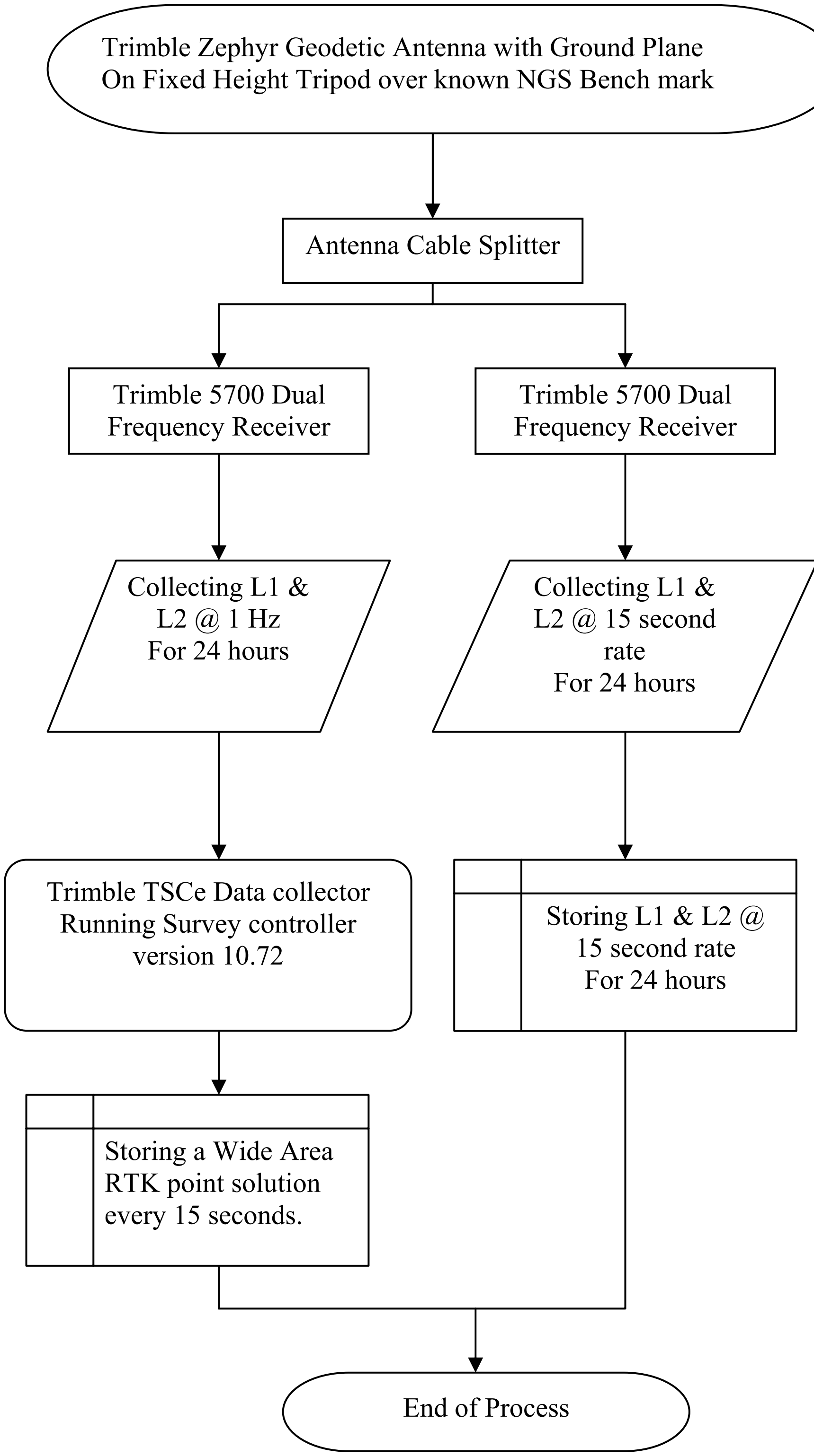

Trimble Zephyr Geodetic Antenna with Ground Plane
On Fixed Height Tripod over known NGS Bench mark
Antenna Cable Splitter
Trimble 5700 Dual Frequency Receiver
Trimble 5700 Dual Frequency Receiver
Collecting L1 & L2 @ 1 Hz For 24 hours
Collecting L1 & L2 @ 15 second rate For 24 hours
Trimble TSCe Data collector Running Survey controller version 10.72
Storing L1 & L2 @ 15 second rate For 24 hours
Storing a Wide Area RTK point solution every 15 seconds.
End of Process

FIGURE 3

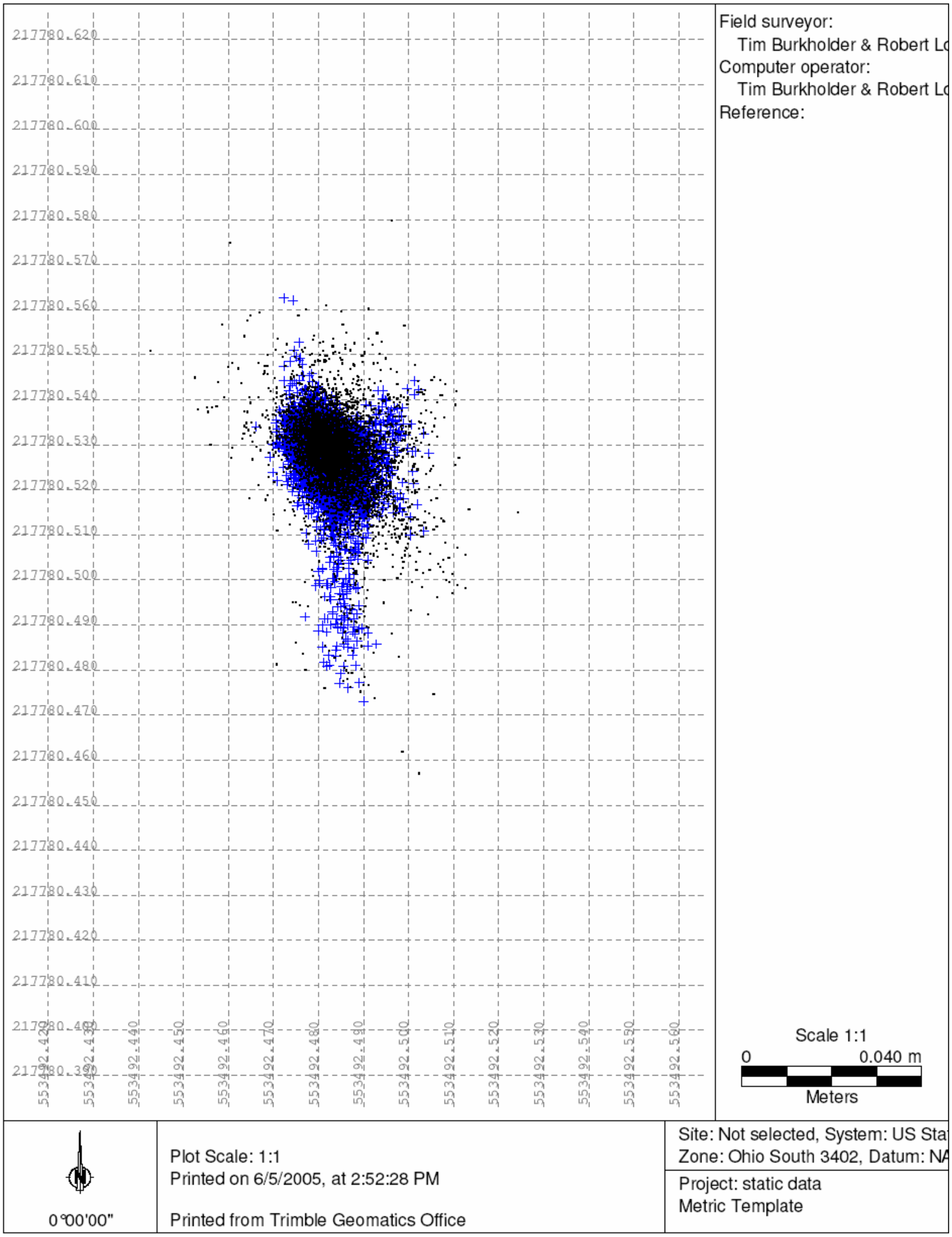

Field surveyor:
Tim Burkholder & Robert Lo
Computer operator:
Tim Burkholder & Robert Lo
Reference:
Scale 1:1
0
0.040 m
Meters
Plot Scale: 1:1
Printed on 6/5/2005, at 2:52:28 PM
Printed from Trimble Geomatics Office
0°00'00"
Site: Not selected, System: US Sta
Zone: Ohio South 3402, Datum: NA
Project: static data
Metric Template

FIGURE 4

	Mean East Difference	Mean North Diff	Mean Height Diff
Hour 1	0.004	0.002	0.004
Hour 2	0.001	0.002	0.004
Hour 3	0.001	0.003	0.009
Hour 4	0.003	0.001	0.015
Hour 5	0.003	0.002	0.001
Hour 6	0.003	0.000	0.007
Hour 7	0.002	0.001	0.002
Hour 8	0.001	0.001	0.014
Hour 9	0.002	0.003	0.009
Hour 10	0.001	0.003	0.003
Hour 11	0.002	0.001	0.005
Hour 12	0.002	0.004	0.022
Hour 13	0.003	0.000	0.009
Hour 14	0.001	0.002	0.001
Hour 15	0.001	0.002	0.003
Hour 16	0.003	0.000	0.002
Hour 17	0.002	0.000	0.004
Hour 18	0.003	0.002	0.018
Hour 19	0.003	0.001	0.005
Hour 20	0.002	0.001	0.009
Hour 21	0.001	0.003	0.016
Hour 22	0.003	0.000	0.005
Hour 23	0.002	0.001	0.004
Hour 24	0.003	0.002	0.006
Hour 25	0.002	0.001	0.014

FIGURE 5

	Mean North Static	Std Dev North Static	Mean North VRS	Std Dev North VRS
Hour 1	217780.525	0.005	217780.523	0.009
Hour 2	217780.528	0.005	217780.529	0.008
Hour 3	217780.527	0.006	217780.529	0.006
Hour 4	217780.526	0.005	217780.527	0.007
Hour 5	217780.525	0.004	217780.527	0.007
Hour 6	217780.528	0.004	217780.529	0.008
Hour 7	217780.527	0.004	217780.527	0.006
Hour 8	217780.531	0.004	217780.532	0.006
Hour 9	217780.530	0.004	217780.533	0.007
Hour 10	217780.526	0.005	217780.530	0.009
Hour 11	217780.530	0.008	217780.532	0.007
Hour 12	217780.512	0.019	217780.515	0.023
Hour 13	217780.526	0.005	217780.525	0.008
Hour 14	217780.524	0.007	217780.526	0.008
Hour 15	217780.526	0.005	217780.528	0.007
Hour 16	217780.523	0.008	217780.522	0.010
Hour 17	217780.527	0.005	217780.528	0.008
Hour 18	217780.532	0.005	217780.534	0.007
Hour 19	217780.528	0.004	217780.528	0.006
Hour 20	217780.530	0.004	217780.531	0.006
Hour 21	217780.528	0.004	217780.531	0.005
Hour 22	217780.527	0.004	217780.528	0.007
Hour 23	217780.526	0.006	217780.525	0.011
Hour 24	217780.527	0.005	217780.529	0.006
Hour 25	217780.523	0.005	217780.522	0.007

FIGURE 6

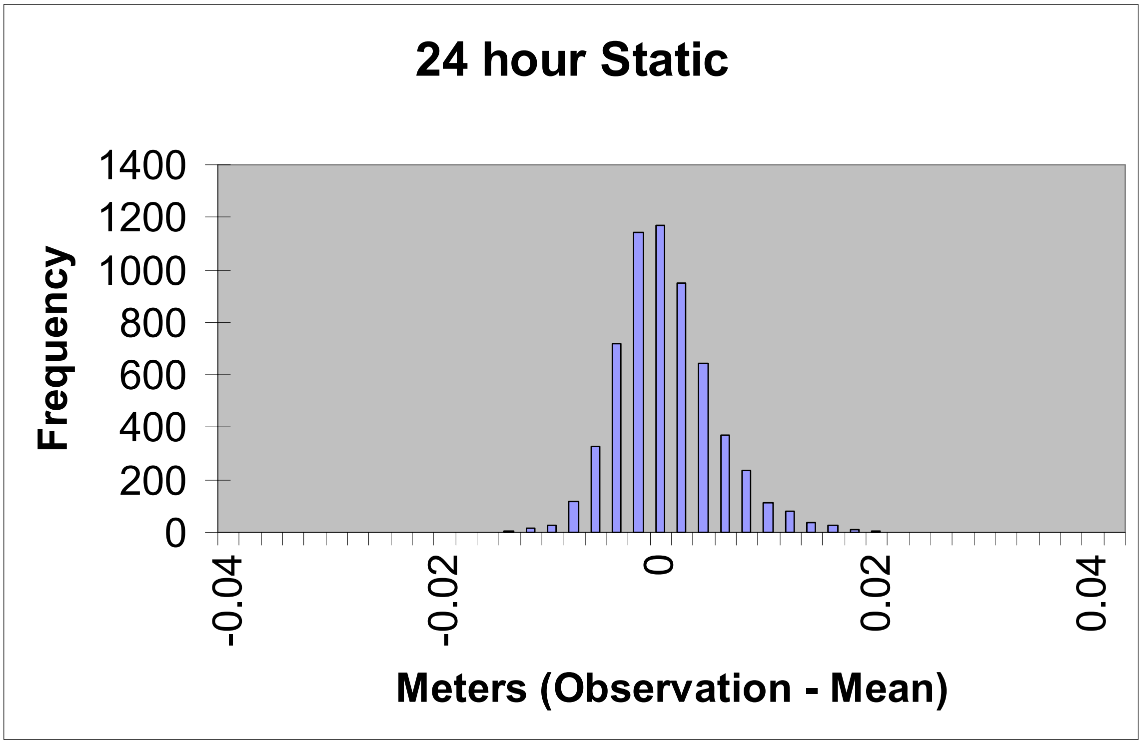

24 hour Static
Frequency
1400
1200
1000
800
600
400
200
0
-0.04
-0.02
0
0.02
0.04
Meters (Observation - Mean)

FIGURE 7

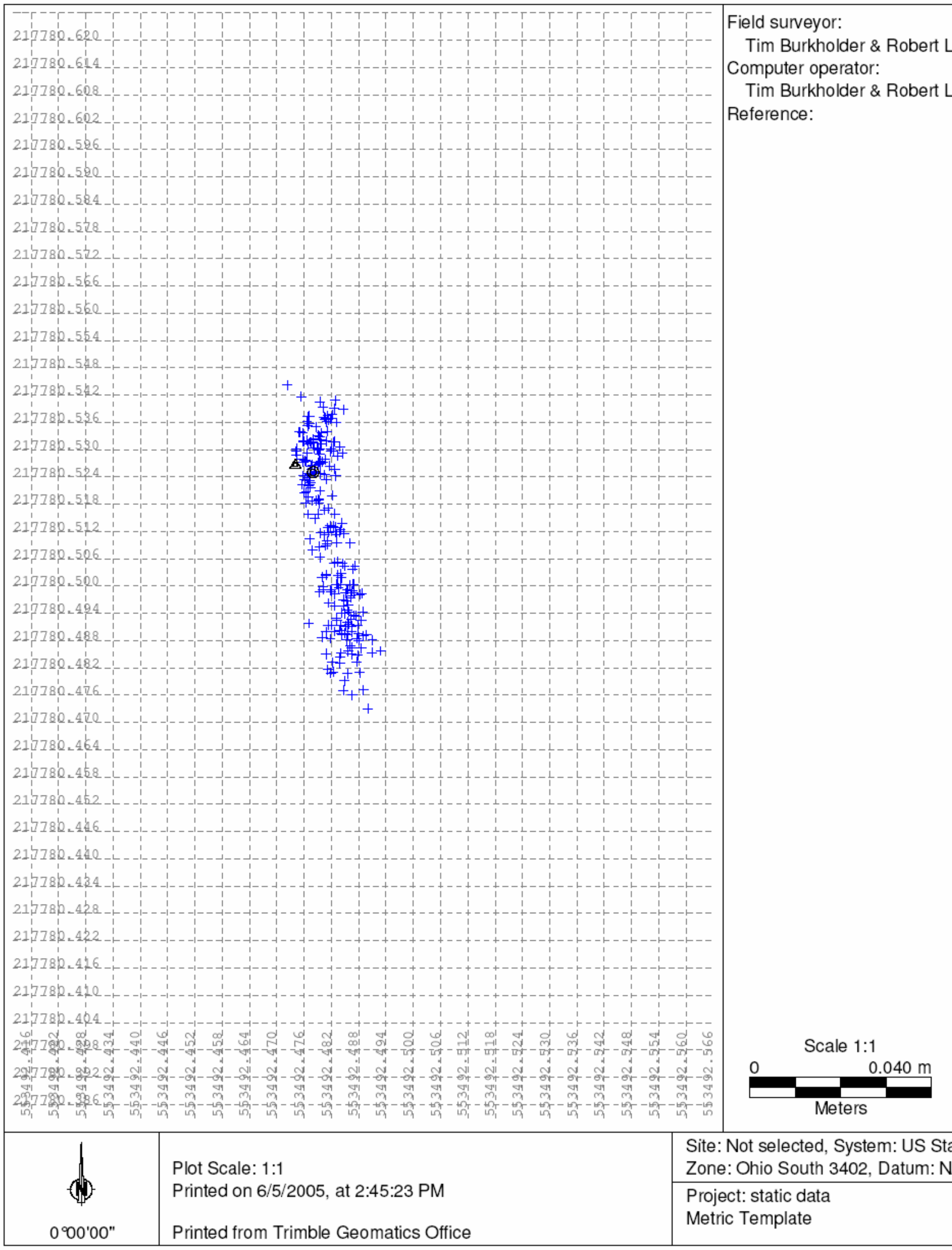


FIGURE 8, Twelfth hour static data

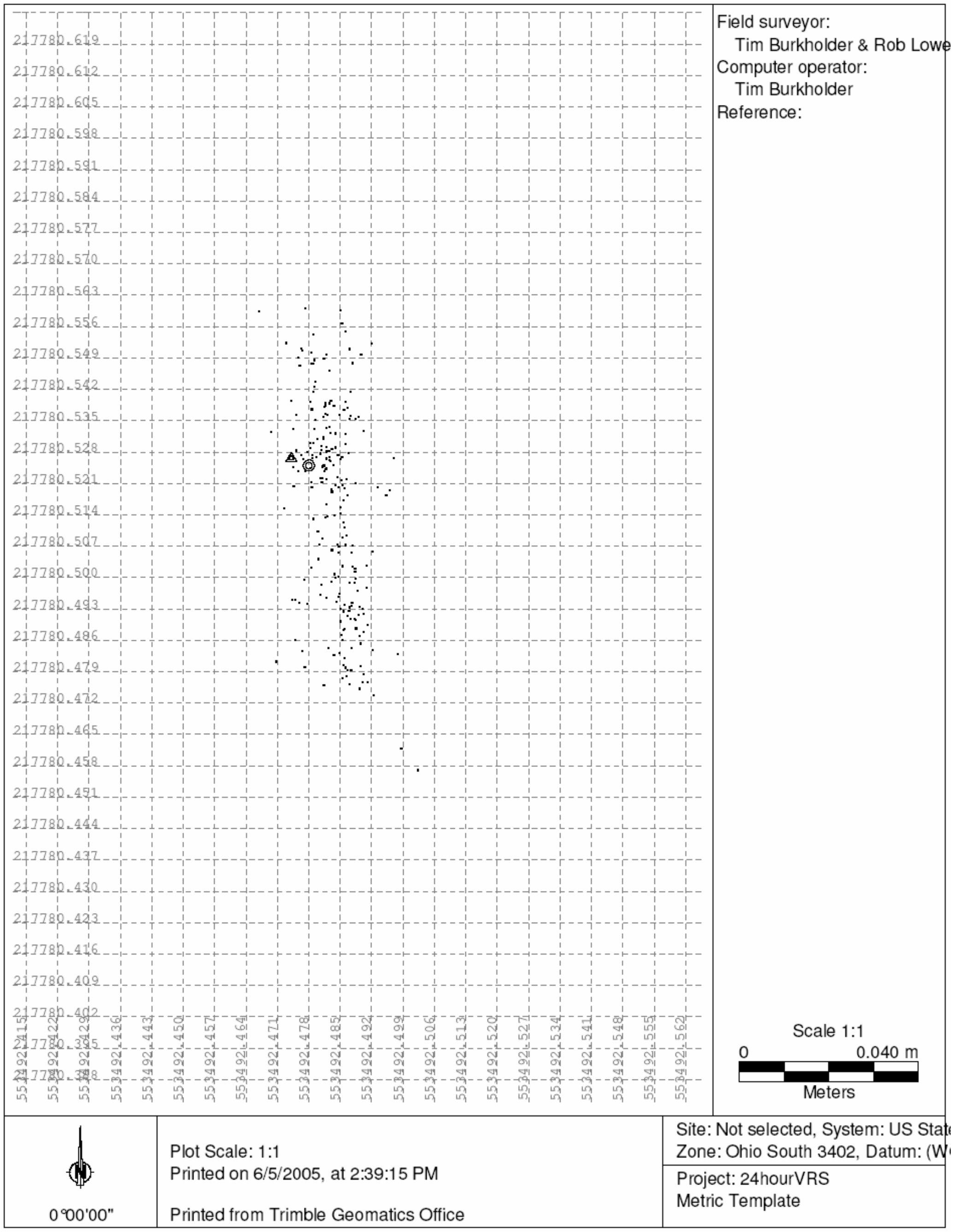


FIGURE 9, Twelfth hour V.R.S. data

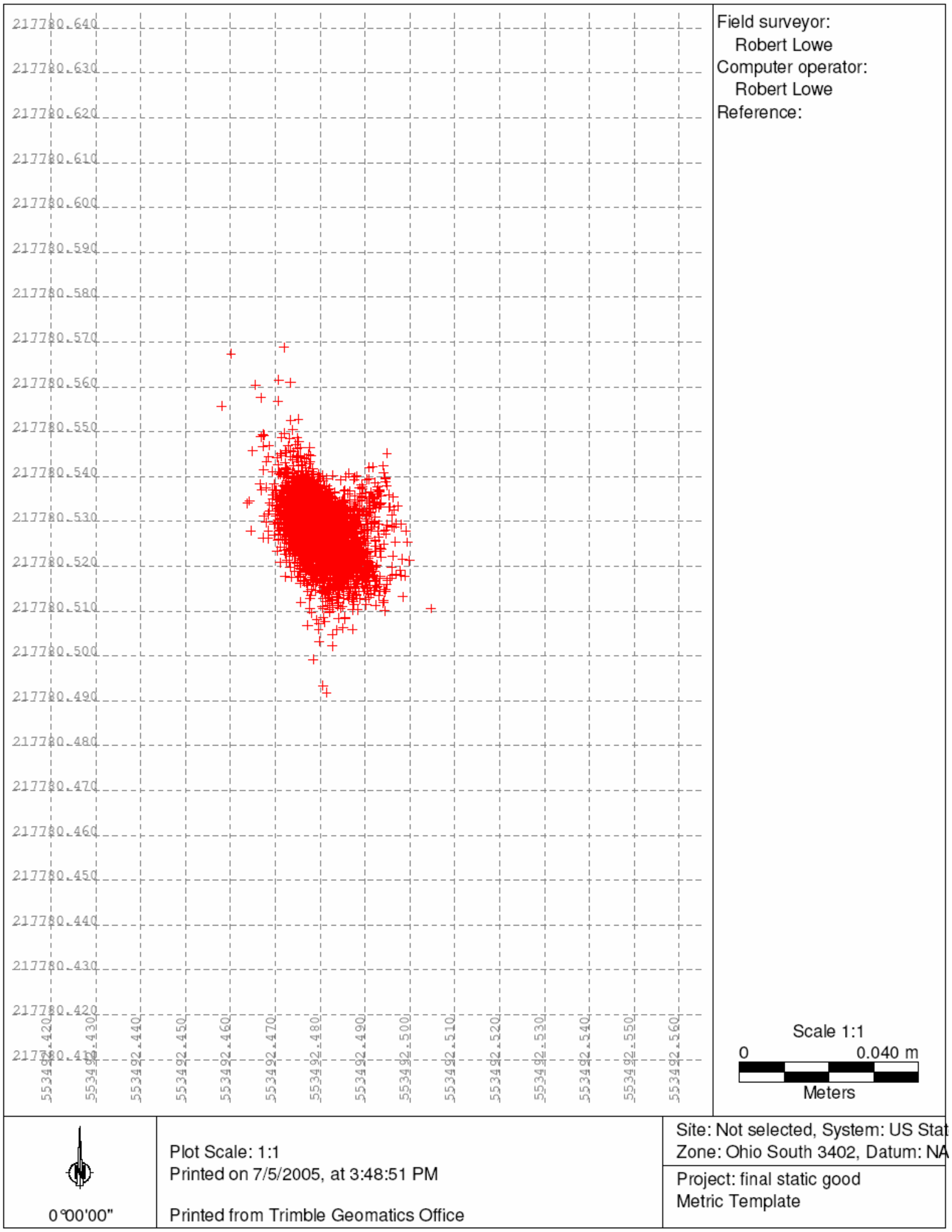


FIGURE 10, Static data filtered for satellite interference

APPENDIX B

SAMPLE BASELINE PROCESSING REPORT

Baseline Summary B3229 (colb to 24hr#2.rnx)

Processed:	Monday, Jan 17, 2005 12:50:04PM
Solution type:	L1 fixed
Solution acceptability:	Solution acceptable
Ephemeris used:	Broadcast
Met Data:	Standard
Baseline slope distance:	144.898m
Elevation mask:	13 degrees
Variance ratio:	3.1
Reference variance:	3.731
RMS:	0.008m
Horizontal Precision 1-sigma (scaled):	0.014m
Vertical Precision 1-sigma (scaled):	0.022m
Start time (GPS Time):	04/09/10, 05:20:30.000 1287, 451230.000
Stop time (GPS Time):	04/09/10, 05:20:30.000 1287, 451230.000
Occupation time:	00:00:00.000

Baseline Components (Mark to Mark)

From:	colb				
Grid		**Local**		**WGS 84**	
Northing	217705.139m	**Latitude**	39°57'35.11262"N	**Latitude**	39°57'35.11261"N
Easting	553368.753m	**Longitude**	83°02'44.74737"W	**Longitude**	83°02'44.74737"W
Elevation	220.163m	**Height**	186.460m	**Height**	186.460m

To:	Continuous				
Grid		**Local**		**WGS 84**	
Northing	217780.496m	**Latitude**	39°57'37.58009"N	**Latitude**	39°57'37.58008"N
Easting	553492.486m	**Longitude**	83°02'39.55333"W	**Longitude**	83°02'39.55333"W
Elevation	217.859m	**Height**	184.152m	**Height**	184.152m

Baseline:					
		NS Fwd			

FIGURE 1.1

Δ Northing	75.357m	Azimuth	58°18'39"	Δ X	116.240m
Δ Easting	123.732m	Ell. Distance	144.876m	Δ Y	65.204m
Δ Elevation	-2.304m	Δ Height	-2.308m	Δ Z	56.852m

Standard Errors

Baseline Errors:					
σ Δ Northing	0.007m	σ NS Fwd Azimuth	8.672 seconds	σ Δ X	0.003m
σ Δ Easting	0.003m	σ Ell.Distance	0.005m	σ Δ Y	0.011m
σ Δ Elevation	0.011m	σ Δ Height	0.011m	σ Δ Z	0.007m

Aposteriori Covariance Matrix

	X	Y	Z
X	1.044e-5m^2		
Y	-1.290e-5m^2	1.278e-4m^2	
Z	4.421e-6m^2	-3.197e-5m^2	4.771e-5m^2

Occupations

		From	To
Point Name:		colb	Continuous
Data file:		colb254f.rnx	24hr#2.rnx
Receiver Type:		5700	5700
Receiver Serial Number:		0220247246	220308883
Antenna type:		Unknown External	Zephyr Geodetic
Measured To:		Bottom of antenna mount	Bottom of antenna mount
Antenna height	Measured	-0.110m	2.000m
	APC	-0.110m	2.053m

FIGURE 1.2

Tracking Summary

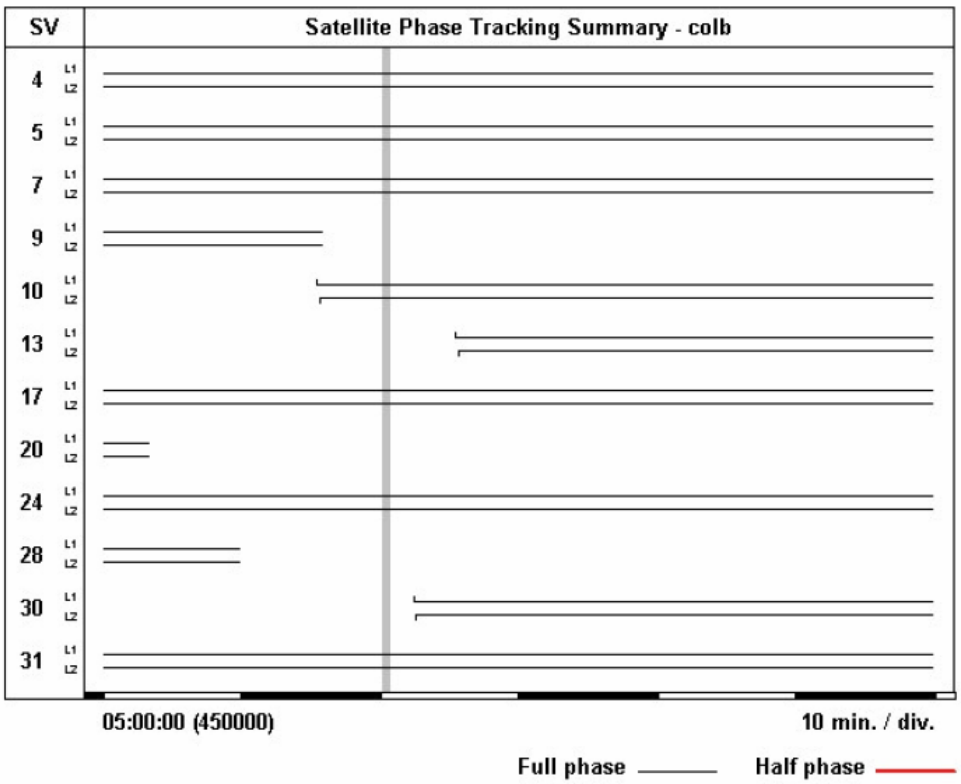


FIGURE 1.3

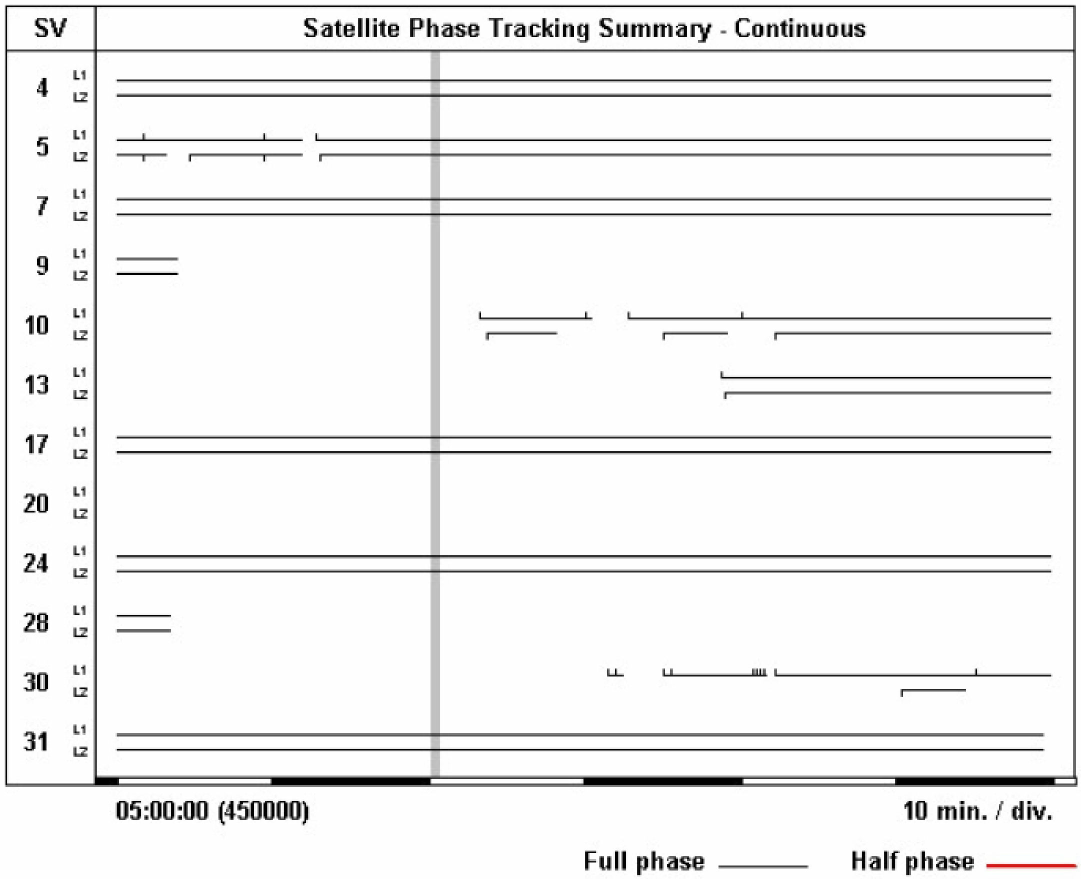

SV
Satellite Phase Tracking Summary - Continuous
4
5
7
9
10
13
17
20
24
28
30
31
L1
L2
05:00:00 (450000)
10 min. / div.
Full phase
Half phase

FIGURE 1.4

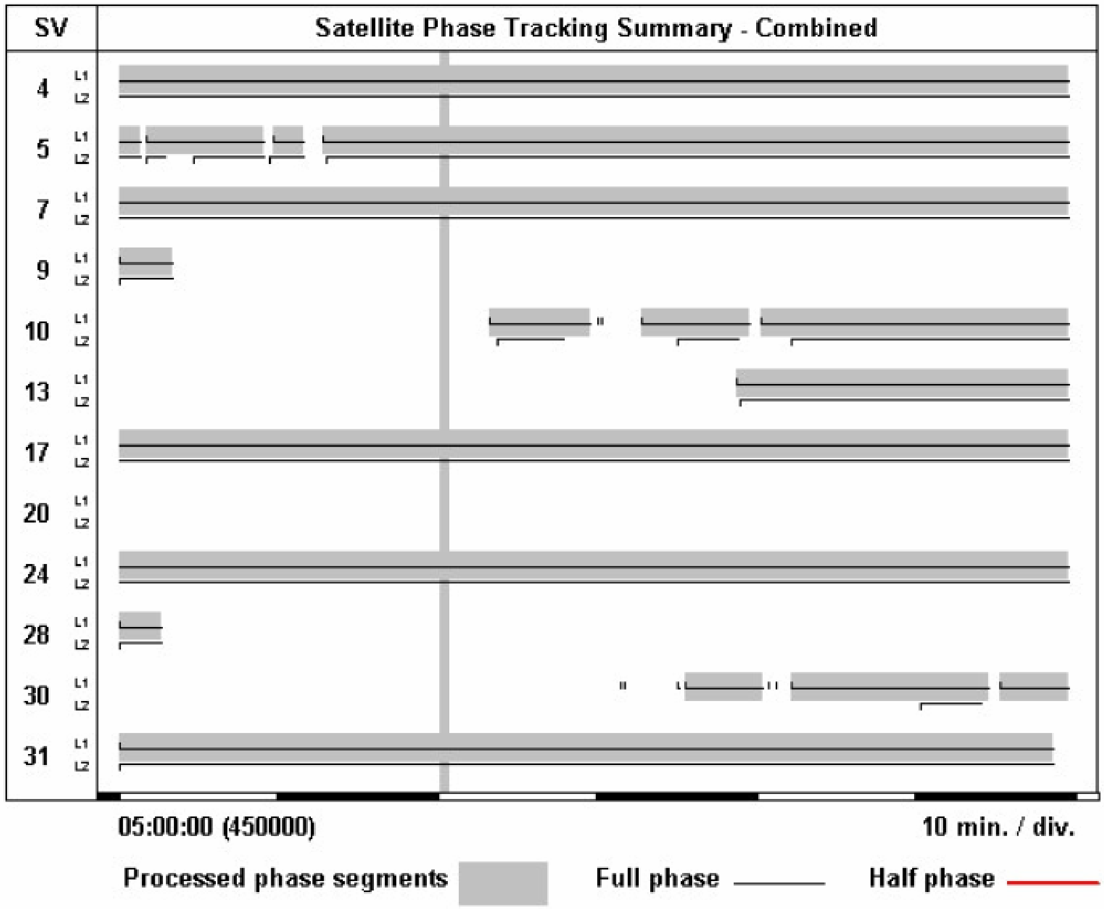
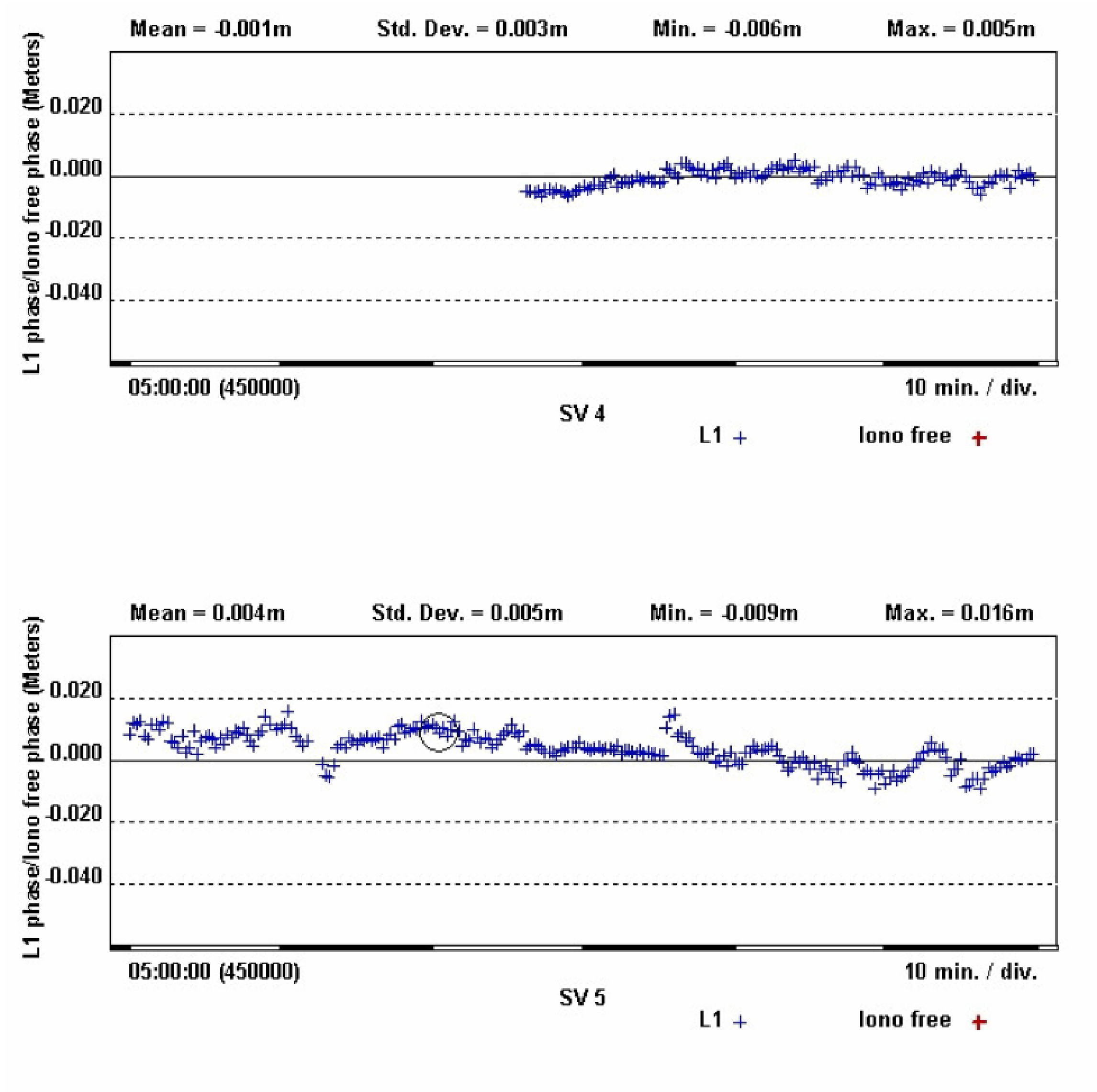
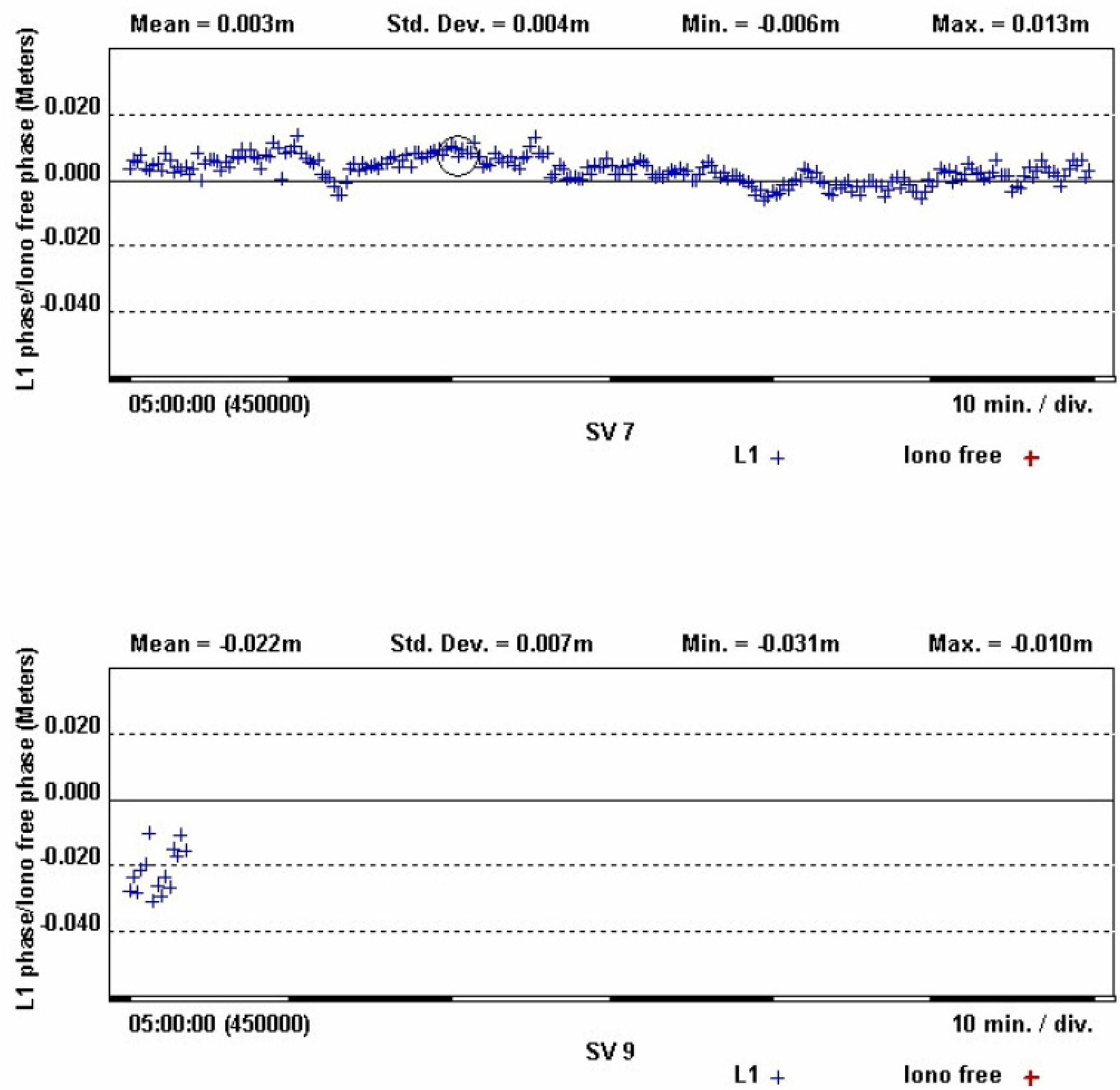

SV
Satellite Phase Tracking Summary - Combined
4
5
7
9
10
13
17
20
24
28
30
31
L1
L2
05:00:00 (450000)
10 min. / div.
Processed phase segments
Full phase
Half phase

FIGURE 1.5



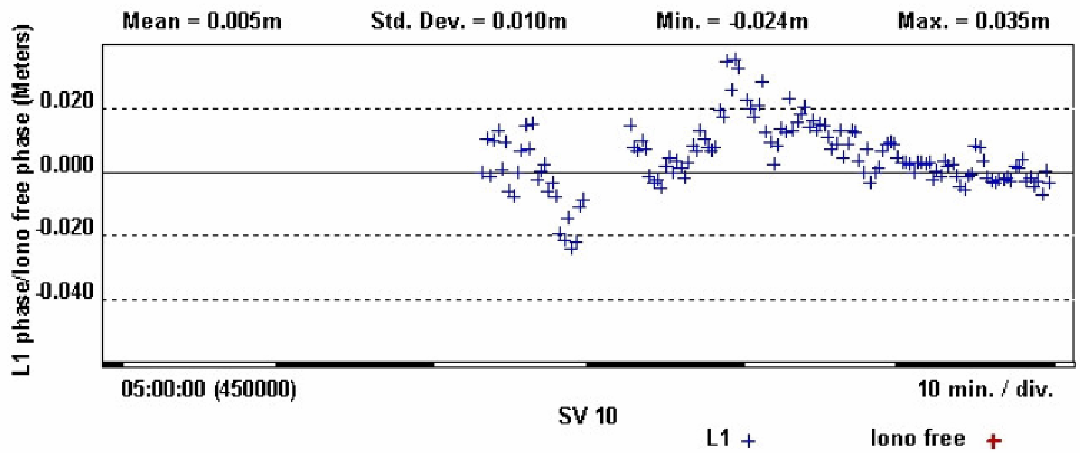
Mean = -0.001m
Std. Dev. = 0.003m
Min. = -0.006m
Max. = 0.005m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 4
L1 +
Iono free +
Mean = 0.004m
Std. Dev. = 0.005m
Min. = -0.009m
Max. = 0.016m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 5
L1 +
Iono free +

FIGURE 1.6



Mean = 0.003m
Std. Dev. = 0.004m
Min. = -0.006m
Max. = 0.013m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 7
L1 +
Iono free +
Mean = -0.022m
Std. Dev. = 0.007m
Min. = -0.031m
Max. = -0.010m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 9
L1 +
Iono free +

FIGURE 1.7


Mean = 0.005m
Std. Dev. = 0.010m
Min. = -0.024m
Max. = 0.035m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 10
L1
Iono free

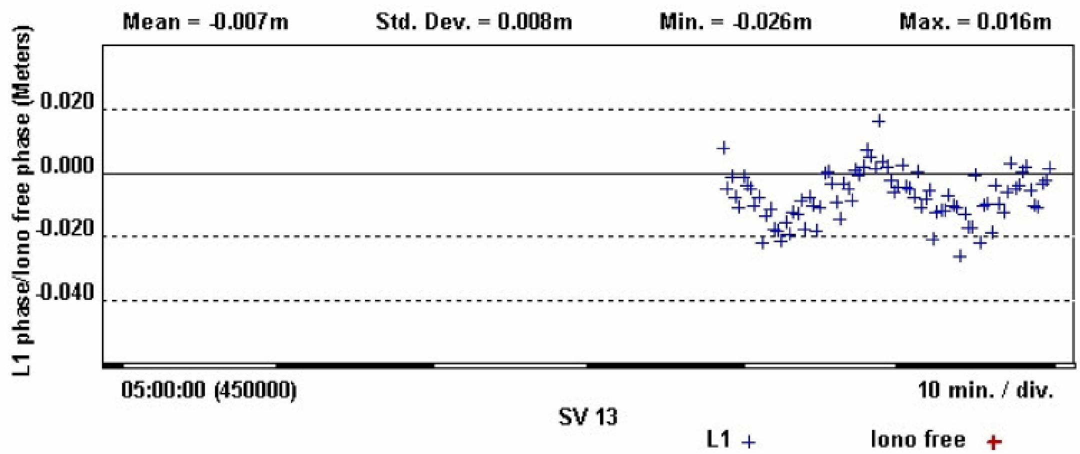
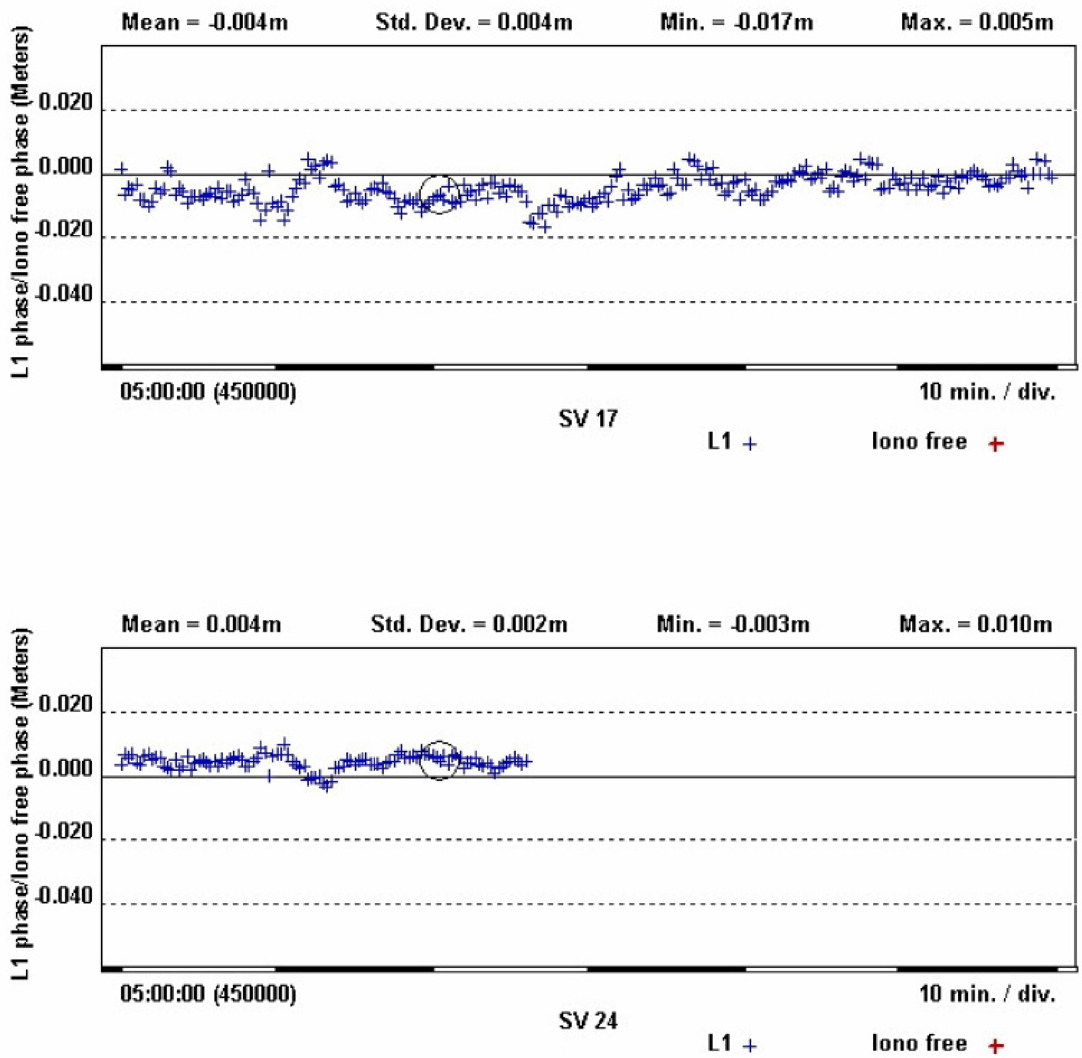

Mean = -0.007m
Std. Dev. = 0.008m
Min. = -0.026m
Max. = 0.016m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 13
L1
Iono free

FIGURE 1.8



Mean = -0.004m
Std. Dev. = 0.004m
Min. = -0.017m
Max. = 0.005m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 17
L1 +
Iono free +
Mean = 0.004m
Std. Dev. = 0.002m
Min. = -0.003m
Max. = 0.010m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 24
L1 +
Iono free +

FIGURE 1.9

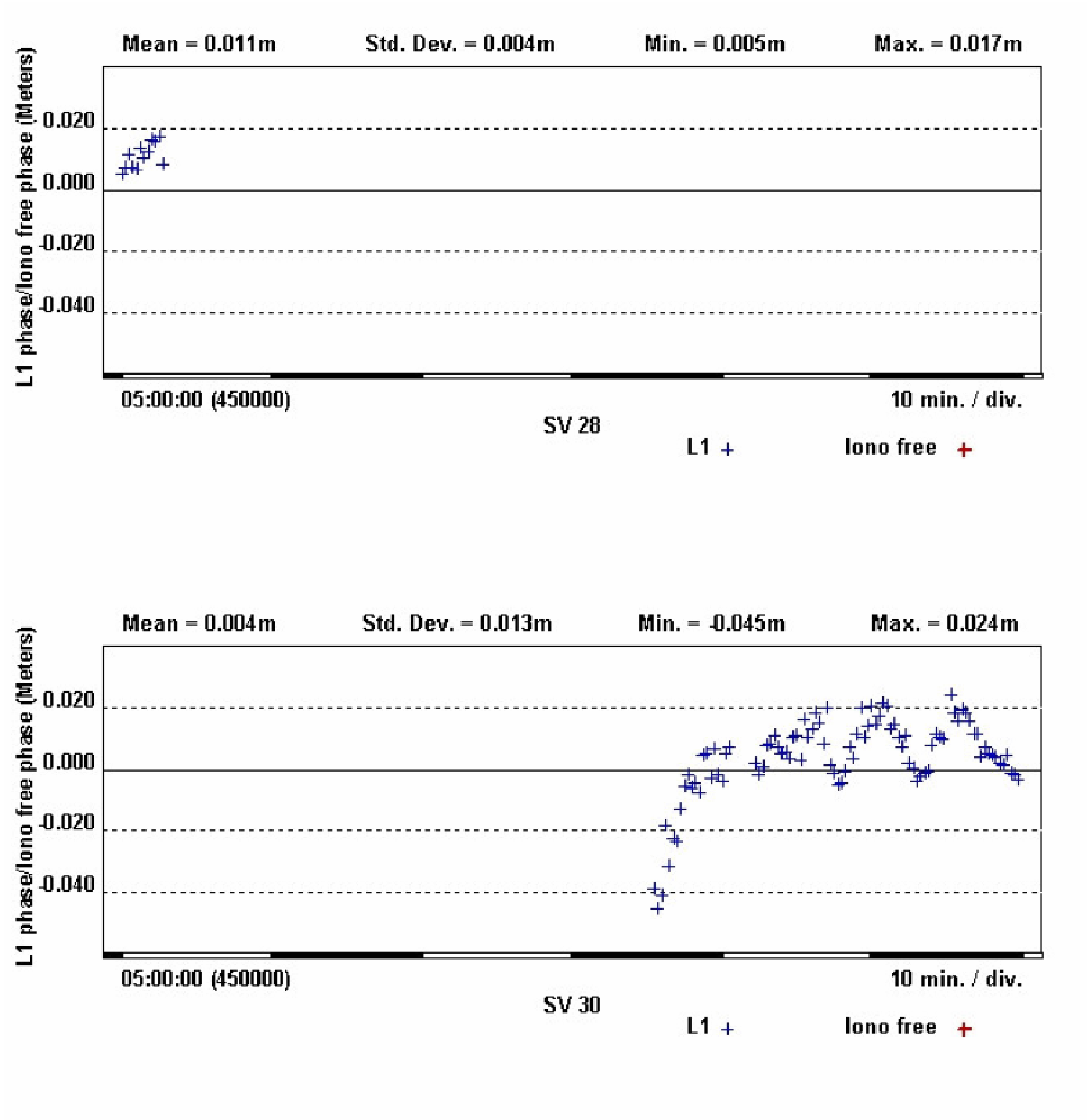
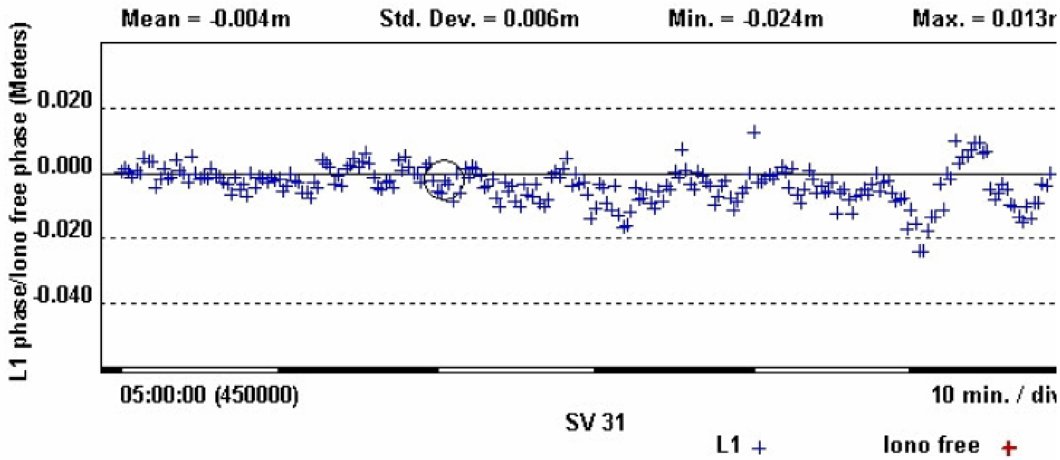

Mean = 0.011m
Std. Dev. = 0.004m
Min. = 0.005m
Max. = 0.017m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 28
L1
Iono free
Mean = 0.004m
Std. Dev. = 0.013m
Min. = -0.045m
Max. = 0.024m
L1 phase/Iono free phase (Meters)
0.020
0.000
-0.020
-0.040
05:00:00 (450000)
10 min. / div.
SV 30
L1
Iono free

FIGURE 1.10



Processing Style - Trimble Default

Elevation Mask	13 degrees
Ephemeris	Broadcast
Solution Type	Fixed

Static

Minimum baseline observation time	120 seconds
Maximum baseline length to attempt a fixed solution :	
Using broadcast ephemeris	200 kilometers
Using precise ephemeris	2000 kilometers

Kinematic

Minimum reference observation time	600 seconds
Minimum static initialization observation time	120 seconds

FIGURE 1.11

Minimum known point initialization ratio	3.000
Minimum OTF processing time	200 seconds

Global

Frequency type	L1
Maximum fixable cycle slip (static processing only)	600 seconds
Maximum iterations (static processing only)	10
Maximum integer search time (static processing only)	30 minutes
Antenna Model	Trimble

Quality

	Single frequency		Dual frequency	
	Flag	Fail	Flag	Fail
RMS acceptance criteria	0.030	0.040	0.020	0.030
Ratio acceptance criteria	3.000	1.500	3.000	1.500
Reference variance acceptance criteria	10.000	20.000	5.000	10.000
Edit multiplier	3.500			

Tropo

Model	Hopfield
Minimum zenith delay interval	2 hours
Use observed met data	Enabled

FIGURE 1.12

Iono

Ambiguity resolution pass (static processing only)	Enabled
Apply to all baselines longer than	10 kilometers
Final pass	Enabled
Apply to all baselines longer than	5 kilometers

Events

Interpolation method	Linear
Number of points to fit	2
Maximum allowed missing epochs	0
Time offset	0 microseconds

OTF Search

Search method	Optimal

FIGURE 1.13